MA 28: Magnonics 2

Time: Thursday 9:30–12:45 Location: H43

MA 28.1 Thu 9:30 H43

Imaging and phase-locking of non-linear spin waves — •Rouven Dreyer[1], Alexander F. Schäffer[1], Hans G. Bauer[2], Niklas Liebing[1], Jamal Berakdar[1], and Georg Woltersdorf[1] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany — [2]Jahnstrasse 23, 96050 Bamberg, Germany

Non-linear processes are a key feature in the emerging field of spin-wave based information processing since they allow to convert uniform spin-wave excitations into propagating modes at different frequencies. Typically, non-linear spin-wave generation is well described by three and four-magnon scattering processes in the small modulation limit. Recently, the existence of non-linear magnons at odd half-integer multiples of the driving frequency (such as 3/2 f_{rf}, 5/2 f_{rf}, etc.) has been predicted for $Ni_{80}Fe_{20}$ at low bias fields [1]. However, it is an open question under which conditions these non-linear spin waves emerge coherently and how they can be manipulated in devices. Using super-Nyquist sampling MOKE [2] we directly image these non-linear spin waves in the strong modulation regime. The spatially-resolved investigation of such excitations in $Ni_{80}Fe_{20}$ elements reveals two distinct phase states [3]. Moreover, we use phase-locking to an external 'seed' frequency to activelymanipulate the phase state. These results open new possibilities for spin-wave sources and phase-encoded information processing with magnons.

[1] H. G. Bauer et al., NC 6:8274 (2015) [2] R. Dreyer et al., PRM 5(6):064411 (2021) [3] T. Makiuchi et al., APL 118, 022402 (2021)

MA 28.2 Thu 9:45 H43

Frequency multiplication by collective nanoscale spin wave dynamics — •Chris Körner[1], Rouven Dreyer[1], Martin Wagener[2], Niklas Liebing[1], Hans G. Bauer[3], and Georg Woltersdorf[1] — [1]Department of Physics, Martin Luther University HalleWittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Institute for Quantum Electronics, ETH Zürich, Otto-Stern-Weg 1, 8093 Zürich, Switzerland — [3]Jahnstrasse 23, 96050 Bamberg, Germany

We observe all-magnetic frequency multiplication and the generation of a 6-octave spanning frequency comb within an extended polycrystalline NiFe layer [1]. We investigate this process by means of super Nyquist sampling MOKE microscopy [2] and diamond NV center spectroscopy. Our experimental observations in conjunction with micromagnetic simulations reveal the mechanism of this unexpected phenomenon.

At low bias fields the magnetization locally tilts due to a magnetic ripple effect in the NiFe film. Driving the magnetization with frequencies far below ferromagnetic resonance, i.e. in the MHz range, causes rapid synchronous switching. These switching processes lead to high harmonic spin wave emission. The spin waves emitted by multiple switching events across the film interfere and form a phase stable coherent spin wave frequency comb extending into the GHz regime.

[1] Koerner et al. Science, 375 (6585), 1165-1169 (2022) [2] Dreyer et al. Phys. Rev. Materials 5, 064411 (2021)

MA 28.3 Thu 10:00 H43

Hybridization Induced Spin-Wave Stop Band — •Christian Riedel, Takuya Taniguchi, and Christian H. Back — Technische Universität München

We present complex spin-wave diffraction patterns in the near-field diffraction limit by using a custom-made time-resolved magneto-optical Kerr effect (TR-MOKE) microscope for visualizing the local and time-resolved dynamic magnetization, i.e. propagating spin-waves. To investigate magnonic interference behaviors, we fabricate a diffraction grating in a 200 nm thick ferrimagnetic YIG film by argon ion-beam etching. A coplanar waveguide (CPW) located parallel to the grating, is used to coherently excite spin-waves. Our results represent the experimental realization of complex spin-wave interference patterns arising from various diffraction gratings, as preliminary investigated by Mansfeld et al.. We further demonstrate that the interference pattern behind the diffraction grating can be tuned through careful selection of the external magnetic field strength. A reduction in the effective magnetic field between the grating antidots can lead to a hybridization of two spin-wave modes and with this to a spin-wave transmission stop-band. This work contributes to the understanding of spin-wave interference behaviors for enhancing the performance of future magnonic devices.

MA 28.4 Thu 10:15 H43

Investigation of Spin Wave Caustics Phenomena — •Franz Vilsmeier[1], Alexis Wartelle[2], Takuya Taniguchi[1], and Christian Back[1] — [1]Technische Universität München — [2]Grenoble Institute of Technology

We present a systematic survey of caustic spin wave beams and their properties in an anisotropic magnetic environment.

Based on the theory from Kalinikos and Slavin for spin waves in soft films [Journal of Physics C: Solid State Physics, 1986, 19, 7013-7033], an anisotropic dispersion relation allows caustic points to exist. Here, several wavevectors with the same group velocity direction can be excited over a broad angular range within the sample plane. These caustic points result in nondiffractive spin wave beams and are characterised by their propagation direction, wavefront angle and wavelength.

Experimentally, we excite the caustic points in 200 nm thick Yttrium Iron Garnet by sending an rf current through a bow-shaped antenna. Time Resolved Kerr Microscopy is used to investigate the propagation behaviour both, spatially, as well as time resolved. We are able to access one caustic pocket and detect caustic-like beams over a range of different rf frequencies and external magnetic field values. Furthermore, the caustic-like beams are used to directly observe anisotropic reflection phenomena and steering of the beams with rotation of the externally applied field. The findings are compared to micromagnetic simulations with the help of Mumax3.

MA 28.5 Thu 10:30 H43

The Optimization of Yttrium Iron Garnet Spin-wave Lenses for Amplification of Spin Waves — •Stephanie Lake[1], Philipp Geyer[1], Rouven Dreyer[1], Niklas Liebing[1], Philip Trempler[1], Evangelos Papaioannou[1], Georg Woltersdorf[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, MartinLuther-Universität Halle-Wittenberg, 06120 Halle, Germany

Exciting magnons in magnetic materials for high-frequency applications is inefficient; one way to improve the process is to focus a manifold of spin waves. Following this idea, we create a magnon counterpart to the nonimaging Fresnel lens concentrator called a "spin-wave lens."

We simulate spin-wave (SW) propagation through funnel-like SW lenses based on the material Yttrium Iron Garnet (YIG) using Mumax [1]. When a frequency of 3.25 GHz and field of 51.62 mT are applied, SW modes with wavelengths 9.4 μm are excited, and furthermore, have a 384-fold increase in their intensity relative to the structure's start.

To test the simulation's accuracy, we fabricate SW lenses out of YIG [2] and measure the precession of excited SWs by a magneto-optic Kerr effect (MOKE) measurement scheme. We conduct several parameter sweeps of geometric characteristics and experimental conditions and currently attain a 51-fold increase in intensity near the funnel's exit for a frequency of 3.68 GHz and magnetic field of 66.15 mT.

[1] A. Vansteenkiste, et al., *AIP Adv.* **4**, 107133 (2014).
[2] F. Heyroth, et al., *Phys. Rev. Appl.* **12**, 054031 (2019).

MA 28.6 Thu 10:45 H43

Exchange spin waves excitation in nanoscale magnonic waveguides using deeply nonlinear phenomena — •Qi Wang[1,2], Roman Verba[3], Björn Heinz[4], Michael Schneider[4], Ondřej Wojewoda[5], Carsten Dubs[6], Norbert Norbert[2], Michal Urbánek[5], Philipp Pirro[4], and Andrii Chumak[1] — [1]Faculty of Physics, University of Vienna, Vienna, Austria — [2]Wolfgang Pauli Institute c/o Faculty of Mathmatics, University of Vienna, Vienna, Austria — [3]Institute of Magnetism, Kyiv, Ukraine — [4]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [5]CEITEC BUT, Brno University of Technology, Brno, Czech Republic — [6]INNOVENT e.V., Technologieentwicklung, Jena, Germany

High-speed and ultrashort waves with pronounced nonlinear phenomena are an ideal medium for wave-based computing. Spin waves, and their quanta magnons, meet all the requirements and are prospective data carriers in future signal processing systems. However, an efficient method for the excitation of short-wavelength spin waves is still an unsolved problem and a major obstacle for broadband spin-wave applications. Here, we present a universal approach to excite spin waves with wavelengths from micrometers down to tens of nanometers in nanoscale waveguides by exploiting deep nonlinear phenomena and validate it experimentally by microfocused Brillouin light scattering spectroscopy. The novel excitation method removes the wavelength limitations imposed by the antenna size, increases the excitation efficiency of short spin waves, and enables direct on-chip integration.

MA 28.7 Thu 11:00 H43

Symmetry of the magnetoelastic interaction of Rayleigh- and shear horizontal-magnetoacoustic waves — •Matthias Küss[1], Michael Heigl[1], Luis Flacke[2,3], Andreas Hefele[1], Andreas Hörner[1], Mathias Weiler[2,3,4], Manfred Albrecht[1], and Achim Wixforth[1] — [1]University of Augsburg, Experimental Physics I and IV — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften — [3]Physics-Department, Technical University Munich, 85748 Garching, Germany — [4]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern

Surface acoustic waves (SAWs) have made their way into many everyday devices. These "nano earthquakes" can be efficiently launched and detected on piezoelectric substrates with periodic metallic gratings. Resonant coupling of SAWs with spin waves (SWs) is the basis for an energy-efficient approach towards SW manipulation. In addition, magnetoacoustic interaction affects the properties of the SAW, which in turn can be used to devise new types of microwave devices. However, SAW-SW coupling is limited to certain experimental geometries, defined by the orientation of the static magnetization with respect to the SW wave vector. This orientation dependence is caused by the SAW mode-specific symmetry of the magnetoelastic driving fields. In this contribution, we demonstrate how the SAW mode-shape determines the symmetry of the magnetoelastic interaction and its nonreciprocal behavior, caused by the SAW-SW helicity mismatch effect [M. Küß et al., Phys. Rev. Applied 15, 034046 (2021)].

MA 28.8 Thu 11:15 H43

Direct maskless magnetic patterning using a cobalt focused ion beam — Javier Pablo-Navarro[1], •Kilian Lenz[1], Nico Klingner[1], Gregor Hlawacek[1], Ryszard Narkowicz[1], Lothar Bischoff[1], Rene Hübner[1], Wolfgang Pilz[2], Fabian Meyer[2], Paul Mazarov[2], and Jürgen Lindner[1] — [1]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [2]Raith GmbH, Konrad-Adenauer-Allee 8, 44263 Dortmund

We present direct maskless magnetic patterning of ferromagnetic nanostructures using a novel liquid metal alloy ion source for focused ion beam systems (FIB). We used a $Co_{36}Nd_{64}$ alloy as the FIB source. A Wien mass filter allows for quick switching between the ion species in the alloy without changing the source. A single $5 \times 1 \times 0.05$ μm^3 permalloy strip served as the sample. Using the FIB we implanted a 300 nm wide track with Co ions. We observed the Co-induced changes by measuring the sample with microresonator ferromagnetic resonance before and after the implantation. Structures as small as 30 nm can be implanted up to a concentration of 10 % at the surface. Such lateral resolution is hard to reach for other lithographic methods. In contrast to electron beam lithography with broad beam ion implantation, the maskless FIB process does not require the complicated and difficult removal of the ion-hardened resist if optical measurements like BLS or MOKE are needed.

MA 28.9 Thu 11:30 H43

Experimental Detection of Magnon Noise Enhancement near Spin Reorientation in $Sm_{0.7}Er_{0.3}FeO_3$ — •Marvin Weiss[1], Andreas Herbst[1], Julius Schlegel[1], Martin Evers[1], Tobias Danegger[1], Andreas Donges[1], Makoto Nakajima[2], Sebastian T. B. Goennenwein[1], Alfred Leitenstorfer[1], Ulrich Nowak[1], and Takayuki Kurihara[1,3] — [1]Department of Physics, University of Konstanz — [2]ILE, Univ. Osaka — [3]ISSP, Univ. Tokyo

Disentangling intrinsic quantum mechanical interactions and thermal fluctuations is especially important for understanding and controlling magnetic phase transitions. In solids, the dynamics of thermal fluctuations of elementary excitations typically proceed on a picosecond timescale. Although optical pump-probe experiments give access to this range, the experimental detection of ultrafast spin fluctuations remains largely unexplored due to their incoherent character. We investigate the elementary dynamics of thermally excited incoherent magnons in the time domain with femtosecond resolution. The experiments are enabled by a novel setup that allows for extracting the correlation of the pulse-to-pulse polarization fluctuations between two temporally and spectrally separated femtosecond probe pulses that transmit through the sample. As a proof-of-principle demonstration, we study the critical phenomena around the spin reorientation transition (SRT) of the orthoferrite $Sm_{0.7}Er_{0.3}FeO_3$. Distinct changes of magnon noise amplitude and dynamics are mapped out around the SRT.

MA 28.10 Thu 11:45 H43

Lattice-driven femtosecond magnon dynamics in α-MnTe — •Kira Deltenre[1], Davide Bossini[2], Mirko Cinchetti[1], Götz S. Uhrig[1], and Frithjof B. Anders[1] — [1]Department of Physics, TU Dortmund University, D-44227 Dortmund — [2]Department of Physics and Center for Applied Photonics, University of Konstanz, D-78457 Konstanz

The femtosecond dynamics of the sublattice magnetizations in the antiferromagnetically ordered phase of α-MnTe is investigated theoretically with linear spin wave theory as a function of an external drive [1]. We assume that collective coherent lattice vibrations generated by laser pulses induce an oscillating Heisenberg coupling thus inducing the driving. The calculated dynamics of the antiferromagnetic order parameter exhibits damped coherent longitudinal oscillations, which decay due to dephasing. The frequency of the oscillations is determined by the external driving phonon. We make contact to experiments [2] by analyzing the spin dynamics for realistic parameters and discussing the effect of oscillating Heisenberg couplings between different types of (next-)nearest neighbors.

[1] K. Deltenre, D. Bossini, F. B. Anders, and G. S. Uhrig, Phys. Rev. B **104**, 184419 (2021)

[2] D. Bossini, S. D. Conte, M. Terschanski, G. Springholz, A. Bonanni, K. Deltenre, F. Anders, G. Uhrig, G. Cerullo, and M. Cinchetti, Phys. Rev. B **104**, 224424 (2021)

MA 28.11 Thu 12:00 H43

Hybrid magnon-quantum spin defects system in SiC — •Mauricio Bejarano[1,2], Francisco J. T. Goncalves[3], Toni Hache[4], Michael Hollenbach[1,2], Christopher Heins[1], Tobias Hula[1,5], Yonder Berencén[1], Georgy V. Astakhov[1], and Helmut Schultheiss[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]X-Fab, Dresden, Germany — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany — [5]Technische Universität Chemnitz, Chemnitz, Germany

Hybrid magnon-quantum spins systems have been gathering scientific interest in the last years due to their increased coupling strength, scalability down to the nanoscale regime and their potential as energy efficient quantum buses. While magnon-mediated control of quantum spins has been demonstrated with NV-centers in diamond, it has remained elusive on the silicon carbide (SiC) platform mainly due to the absence of a resonance overlap between the magnetic system and the spin-defect center. Here we circumvent this challenge by harnessing non-linear magnon scattering processes taking place in a magnetic vortex to access spin-wave eigenmodes that overlap with the intrinsic resonance of silicon vacancy defect centers in 4H-SiC. Our results offer a route to develop hybrid magnon-quantum spins systems that benefit from the electrical and optical properties of SiC for future quantum computing applications. This work was supported in part by the German Research Foundation under Grants SCHU 2922/4-1 and AS 310/9-1.

MA 28.12 Thu 12:15 H43

Topological magnons driven by the Dzyaloshinskii-Moriya interaction in the centrosymmetric ferromagnet Mn_5Ge_3 — •Manuel dos Santos Dias[1,2], Nikolaos Biniskos[3], Flaviano José dos Santos[4], Karin Schmalzl[5], Jörg Persson[6], Nicola Marzari[4], Stefan Blügel[2], Thomas Brückel[6], and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, FZ Jülich & JARA, Jülich, DE — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, Duisburg, DE — [3]FZ Jülich, Jülich Centre for Neutron Science at MLZ, Garching, DE — [4]Theory and Simulation of Materials and National Centre for Computational Design and Discovery of Novel Materials, EPFL, Lausanne, CH — [5]FZ Jülich, Jülich Centre for Neutron Science at ILL, Grenoble, FR — [6]FZ Jülich, Jülich Centre for Neutron Science and Peter

Grünberg Institut, JARA-FIT, Jülich, DE

The Berry phase of electrons and magnons can lead to various unique transport effects and protected edge states of topological nature. Here, we show theoretically and via inelastic neutron scattering experiments that bulk ferromagnetic Mn_5Ge_3 hosts topological Dirac magnons. Although inversion symmetry prohibits a net Dzyaloshinskii-Moriya interaction in the unit cell, it is locally allowed and is responsible for the gap opening in the magnon spectra. This gap is predicted and experimentally verified to close by rotating the magnetization from being parallel to being perpendicular to the *c*-axis. The tunability of Mn_5Ge_3 by chemical doping or by thin film nanostructuring makes it an exciting new platform to explore and design topological magnons.

MA 28.13 Thu 12:30 H43

Electric field control of magnons in magnetic thin films: Ab initio predictions for two-dimensional metallic heterostructures — •Alberto Marmodoro[1], Sergiy Mankovsky[2], Hubert Ebert[2], Jan Minár[3], and Ondřej Šipr[1,3] — [1]Institute of Physics (FZU) of the Czech Academy of Sciences, Prague, Czech Republic — [2]Department of Chemistry, Ludwig-Maximilians-University (LMU), Munich, Germany — [3]New Technologies Research Centre, University of West Bohemia, Pilsen, Czech Republic

We report on a possible venue to control magnons in 2D heterostructures by an external electric field acting across a dielectric barrier [1]. By performing ab initio 2D TB-KKR calculations for a Fe monolayer and Fe bilayer, both suspended in vacuum and deposited on Cu(001), we demonstrate that external electric field can significantly modify magnon lifetimes and that these changes can be related to field-induced changes in layer-resolved electronic Bloch spectral function. Further changes appear in cases with more than a single magnetic layer, and are strongly dependent on the presence of the substrate.

[1] Phys.Rev. B 105, 174411 (2022)